8-8-1977

Distribution and Behavior Study of Diurnal Tree Squirrels in Portland, Oregon, with Emphasis on the Western Gray Squirrel (Saiurus grieeus griseus Ord) and the Western Fox Squirrel (S. niger rufiventer E. Geoffroy St.-Hilaire)

Ira Young Rice
Portland State University

10.15760/etd.2539

AN ABSTRACT OF THE THESIS OF Ira Young Rice, III for the Master of Science in Biology presented 8 August 1977.

Title: Distribution and Behavior Study of Diurnal Tree Squirrels in Portland, Oregon, with Emphasis on the Western Gray Squirrel (*Sciurus griseus griseus* Ord) and the Western Fox Squirrel (*S. niger rufiventer* E. Geoffroy St.-Hilaire)

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

[redacted]

Richard B. Forbes, Chairman

[redacted]

David T. Clark

[redacted]

John H. Wiftz

[redacted]

Larry W. Price

Populations of diurnal tree squirrels in the Portland area were located by mail surveys, personal interviews, and field inspections. Pine squirrels were found to reside in thickly wooded residential areas with dense understories and running water nearby. Western gray squirrels occupied habitats in relatively quiet residential neighborhoods, in areas well supplied with mast crops. Western fox squirrels were found to coexist with gray squirrels in their preferred habitat, and also to thrive in park settings with few mast trees and high activity and noise levels. In areas occupied by both fox and gray squirrels, dominant-subordinate relationships were noted. Each species tolerated the others.

The behavior study consisted of live-trapping, marking, and observing populations of squirrels. Data gathered included body weights, activity peaks, food items utilized, predation, and social behavior. In one park, distinct groups of fox squirrels utilized distinct feeding areas.

DISTRIBUTION AND BEHAVIOR STUDY OF DIURNAL TREE SQUIRRELS IN PORTLAND, OREGON, WITH EMPHASIS ON THE WESTERN GRAY SQUIRREL (*Sciurus griseus griseus* ORD) AND THE WESTERN FOX SQUIRREL (*S. niger rufiventer* E. GEOFFROY ST.-HILAIRE)

by

IRA YOUNG RICE, III

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
in
BIOLOGY

Portland State University

1977

TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

The members of the Committee approve the thesis of Ira Young Rice, III presented 8 August 1977.

[redacted]

Richard B. Forbes, Chairman

[redacted]

David T. Clark

[redacted]

John H. Wirtz

[redacted]

Larry W. Price

APPROVED:

[redacted]

W. Herman Taylor, Jr., Head, Department of Biology

[redacted]

Stanley E. Rauch, Dean of Graduate Studies and Research

ACKNOWLEDGEMENTS

There are many people who contributed to my research and they are too numerous to mention individually. I am indebted to those who volunteered information on the survey sheets. Also, I owe many thanks to the owners of private land who allowed me to make observations on their property.

I would like to recognize Dr. Richard B. Forbes for all the time he spent with me and the advice he gave to me as my research advisor and chairman of my graduate committee. I would also like to acknowledge the help of the other members of my graduate committee: Dr. David T. Clark, Dr. Larry W. Price, and Dr. John H. Wirtz.

Most of all I wish to thank my parents for their moral and financial support during my two years of research. Without their help this research would not have been conducted. I am also very grateful to my wife for encouraging me to keep working until the project was completed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The need for more information on urban wildlife was emphasized by Gill and Bonnett (1973). Diurnal tree squirrels are among the most common wildlife in cities, yet surprisingly there have been few studies on these animals in urban environments. Cox (1970) studied gray squirrels (*Sciurus carolinensis*) in a city park in Toronto and found that the squirrels adjusted their peak activity periods to peak human activity periods. Cross (1942) noted that ground-level activities of gray squirrels in Virginia were easy to observe in "semi-tame" squirrels living in park-like environments. Hathaway (1973) studied the ecology of gray squirrels living in a city cemetery and determined that human efforts to maintain the aesthetics of the cemetery halted the natural succession of plant growth at the stage preferred by the squirrels. Hathaway also noted that the combination of disease, automobiles, and predators served as checks on the growth of urban wildlife populations. Flyger (1974) observed that urban tree squirrel populations make excellent subjects for research by colleges and universities located in urban settings. Baldwin (1969) studied the problems of genetic drift in tree squirrel populations isolated in wooded sections in urban communities.

Although no comprehensive life history studies have

been made on the diurnal tree squirrels in Portland, studies on the three species that occur here have been conducted elsewhere. Allen (1943), Baumgartner (1940), Chapman (1940), and Hicks (1942) have all reported on the western fox squirrel (*Sciurus niger rufiventer*). Ingles (1947), Stienbecker and Browning (1970), Stienbecker (1977), Bailey (1936), and Cross (unpublished) have examined the life history and food habits of the western gray squirrel (*Sciurus griseus griseus*). Research on the biology and social organization of the pine squirrel (*Tamiasciurus douglasii douglasii*) has been presented by Bailey (1936) and Smith (1968).

The displacement of one species of tree squirrel from its original habitat by another tree squirrel species has been recorded. Middleton (1931) and Shorten (1954) reported interactions between the native red squirrel (*S. leucurous*) and the gray squirrel introduced in the British Isles. Terrill (1941) and Allen (1943) have examined the possibility of the fox squirrel displacing the gray squirrel from various parts of the United States.

This study sought to ascertain the distribution and interactions in Portland, Oregon, of the pine squirrel, the western gray squirrel, and the western fox squirrel (introduced in Portland and elsewhere in the Willamette Valley). In particular, interactions between the western fox squirrel and western gray squirrel were studied in order to shed some

light on the question of whether the western fox squirrel is displacing the western gray squirrel from preferred habitat of the latter within the city.

TECHNIQUES AND PROCEDURES

Distributional Study

The study lasted from 1 March 1976 to mid-October 1976. The areas studied included the northeast and southeast sections of Portland west of 82nd Avenue, and the southwest section of the city south of U.S. Highway 26.

Portland, located in Multnomah County, Oregon, lies near the confluence of the Columbia and Willamette Rivers, and is bounded by parallels 45° 20' and 45° 40' north latitude and meridians 122° 25' and 122° 45' west longitude. The city is in the western humid transition life zone (Bailey, 1936). The topsoils of the area are predominantly composed of alluvial materials. The topography of the city varies, with elevations ranging from near sea level to 384 meters above sea level in the Tualatin Mountains in southwest Portland. Portland has a moderate climate with long frost-free growing seasons, moderate heavy rainfall, mild rainy winters, and warm to hot dry summers. The average minimum temperature for January, the coldest month, is above freezing; the average maximum temperature for July, the hottest month, is less than 26.6° C. Average annual precipitation is around 100 cm. Prevailing winds are from the northwest in summer and from the southeast during the cooler months with the strongest winds gusting from the south. The mean

annual windspeed is 7.8 mph, and only twice since records have been kept have windspeeds exceeded 75 mph. The average percent of possible sunshine is 48%.

The moderately heavy rainfall and mild climate support a lush vegetation which can be a deterrent to certain aspects of fieldwork. The main forest trees are Douglas fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Pacific dogwood (*Cornus nuttallii*), bigleaf maple (*Acer macrophyllum*), Oregon ash (*Fraxinus latifolia*), red alder (*Alnus ruber*), cascara buckthorne (*Rhamnus purshiana*), Pacific mandrone (*Arbutus manziesii*), and Oregon white oak (*Quercus garryana*). Undergrowth includes English ivy (*Hedera helix*), grape (*Vitis spp.*), huckleberry (*Vaccinium spp.*), blackberry (*Rubus sp.*), nettles (*Urtica spp.*), poison oak (*Rhus diversiloba*), Oregon grape (*Berberis* spp.), ferns (*Polypodiaceae*), and smaller deciduous trees. The above data on vegetation is from Trimble (1963); data on climate is from Trimble (1963) and Anonymous (1976).

Information on the occurrence of diurnal tree squirrels within the study area was gathered in several ways. In the initial stages of the project I conducted personal interviews with several faculty members of the biology departments of universities and colleges in the Portland area in order to determine the location of tree squirrel populations. City park officials were also inter-

viewed to determine and confirm locations of squirrels. As I visited areas suggested as locations where squirrels had previously been observed, I often queried nearby residents and workers. As a result of such interviews, I could frequently verify the existence of squirrel populations in the area and obtain information on the history of these populations.

Mail surveys were conducted and found to be most fruitful. Survey sheets were sent out to people residing in all sections of Portland's city limits and surrounding areas. Two mail surveys were made, one through the U. S. Postal Service, and the second through the campus mail service of Portland State University. The mail survey conducted through the U. S. Postal Service was directed at parties who were thought to be well acquainted with Portland. Personnel of transportation companies (Tri-Met Bus Co., and local taxi companies), the Portland City Fire Department, the Portland City Police Bureau, and the U. S. Postal Service were asked to respond to the survey sheet. Approximately 70 of these survey sheets were mailed. A similar survey sheet was used in a much larger mail survey conducted of Portland State University's faculty and staff. This sheet is shown in Figure 1. Approximately 700 survey sheets were distributed to this group. Out of the total number of questionnaires sent, about 200 were returned with some form of information on them.

PORTLAND STATE UNIVERSITY
p.o. box 751
portland, oregon
97207
503/229-3851

biology department

19 February 1976

TO: P.S.U. faculty and staff

FROM: Ira Y. Rice, Biology

RE: Portland area tree squirrel populations

My M.S. thesis research in Biology deals with the behavior of tree squirrels (western gray, fox, and pine squirrels) in the Portland area. I am particularly interested in the distribution and social interactions of squirrels in and near residential areas.

It would be helpful to me if you would indicate in the space below the locations of tree squirrel populations you may have noticed in the past few years. The locations of the populations are of primary importance, but the other information would also be helpful.

When you have finished with the sheet, just fold it so that my name on the reverse side shows, staple or tape the sheet closed, and drop it in the interoffice mail. Thank you for your help.

Location of Squirrels	Brief Description, or Common Name of Squirrel	Approx. Numbers	Last Seen

Figure 1. Sample of a Survey Sheet.

Information acquired by means of the mail surveys, personal interviews, and city maps was used to compile a list of 66 locations where tree squirrel populations were likely to occur. Upon visiting all 66 locations twenty-one were found to contain squirrel populations. The presence of squirrels could be determined by visual observation, by hearing their calls, by listening for gnawing noises emitted while the squirrels (hidden from view) opened nuts, or by locating shells of nuts or waste from other types of food eaten in a characteristic tree squirrel fashion. Evidence of squirrels was not always forthcoming with each visit to a site, possibly because no squirrels existed at that location, or because their activity was for some reason repressed at that time.

As each site was visited, several environmental factors were recorded, including a brief description of vegetation, the presence of humans and other animals, the presence of bodies of water, the date, time of day, sky conditions, wind speed, and approximate temperature. As populations of squirrels were confirmed, data was recorded on species of squirrels seen, approximate number of each species seen, and a brief description of the behavior of the squirrels during the time of observation. This information is summarized in Table I.

Behavioral Study

Early in the study, it was not certain what mixtures of species of tree squirrels might occur in Portland. I decided that better information on interactions among species could be obtained if single-species populations could be studied as well. Single-species populations of pine squirrels and fox squirrels were located. Only one population of western gray squirrels was found in the study area, and it was mixed with fox squirrels. In an effort to locate single-species population of western gray squirrels, a search was conducted outside the study area into some of the suburbs of Portland. Although no such populations were discovered, another fox squirrel-gray squirrel population was found in Tigard, Washington County.

I employed several methods in studying these animals. One method was to observe general squirrel behavior while conducting the distributional study. Another method involved the use of color-coded collars which made it possible to observe squirrels identifiable as individuals.

A permit from the Portland Bureau of Parks and Public Recreation to live-trap, mark and release tree squirrels was granted on June 21, 1976 and was valid until October 31, 1976. The permit authorized me to live-trap squirrels in the mornings from 5:30 AM to 8:00 AM and occasionally in the afternoon. It also granted permission to place colored

collars on the squirrels for the duration of the study.

Two sizes of National live traps (Tomahawk Live Trap Corp., Tomahawk, WI) were used. The smaller measured 5" x 5" x 16"; it appeared to discourage the larger tree squirrels from entering. The larger trap measured 6" x 6" x 19" and was more successful in trapping tree squirrels. The galvanized steel wire traps I used proved less than fully satisfactory because of the numbers of injuries they caused to captured squirrels. Flyger (1955) obtained similar results in using heavy wire traps. He found that the squirrels became alarmed when humans or other animals approached, and threw themselves against the wire sides of the trap. Flyger then used wooden traps, and found that injuries were greatly reduced. Wire traps were a special problem in this study because of dogs, which would rush upon the captured squirrels and attempt to bite them through the traps. However, wire traps were used because they were available. Traps were placed at locations which were previously observed to be favorite feeding areas of squirrels. The traps were usually placed on the ground at the bases of trees which squirrels were frequently seen to climb. Baits used included American chestnuts (*Castanea dentata*), horse chestnuts (*Aesculus hippocastanium*), acorns (*Quercus* spp.), filberts (*Corylus* spp.), black walnuts (*Juglans nigra*), and English walnuts (*Juglans regia*). English walnuts were found to be the most effective bait.

The western gray and fox squirrels of Mt. Tabor Park thwarted all my trapping attempts. However, the fox squirrels at Pier Park were mostly hand-fed, and "semi-tame" as described by Cross (1942). These animals readily entered baited traps. Unfortunately, Pier Park was among the least ideal of trapping sites in another sense. Several members of the Pier Park community took pride in their squirrels and fed them daily, usually early in the morning. The feeding times occasionally coincided with my trapping activity. Some residents took offense at the trapping and contacted the City Park Commissioner's office to voice their disapproval. The result was an agreement between the Park Commissioner's office and me that trapping would be discontinued although observations could continue. Seven squirrels had been trapped and marked before that time. At the request of the grounds crew foreman at Pier Park, the marked squirrels were retrapped and their collars removed as the expiration date of the trapping permit approached. This was accomplished by mid-October 1976.

Wire cones and a burlap sack were used to handle trapped squirrels. Use of cones for handling squirrels has been described by Allen (1943), Liscinsky (1951) and Flyger (1955). However, I found this method of handling to be unsatisfactory since the squirrels tended to abrade their heads on the wire and cut their heads by rubbing against sharp edges in the cone. Cross (1942) described the use of a holding bag made of 1/4" netting, a procedure later used

by Allison (1953). A tared burlap sack was used in this study in the same way as Cross (unpublished) used large dark cloth sack. A trapped squirrel was allowed to pass from the trap to the sack, in which the animal tended to remain quieter and thus not to injure itself. The squirrel was then grasped behind the head through the sack and the sack was peeled back to expose the squirrel's head. Instead of anesthetizing the animals as Cross (unpublished) did, I examined the squirrels, marked them, and then released them. A hand-held scale (Ohaus Model 8014) was used to weigh the animals to the nearest 10 g.

Flyger (1955) successfully used fur dye for identification of individual squirrels in his study. I tried hair coloring dyes for marking squirrels but this proved unsatisfactory because of the amount of time required to apply the dye, its poor visibility once applied, and the messiness of the procedure. Accordingly, I decided to mark squirrels with color coded collars. I used a two-part collar. One component of the collar was a plastic cable tie, a lightweight, plastic strip which operates much like threading the end of a rope through a loop in the other end. However, once the end is inserted into the hole, it can move only in the direction which tightens the collar. Thus, the collar can be adjusted down to the size best suited to the individual squirrel. The excess part of the collar is trimmed off. Two sizes of cable ties were used satisfactorily, 8" x 3/8"

x 3/16" and 11-1/4" x 1/4" x 3/16". A second component to the collar was a sleeve through which the cable tie was inserted before the collar was cinched down. The sleeves were constructed of cloth-like colored plastic. The material was lightweight, durable, and water resistant. The sleeves could consist of one or more colors in different sequences. Five different colors of material were used in the study and no more than two colors were used per sleeve. The sleeves were 2-1/2" long and 1/4" wide. Before a squirrel was released, the toenail on the fifth digit of the left hind foot was clipped with nail clippers so I could determine whether the squirrels were able to rid themselves of their collars. The collars could be removed easily after the squirrels were retrapped. With a coat hanger one could hook the collar through the trap and pull it against the wires of the trap where it could be cut with nail clippers or scissors.

RESULTS

Distributional Study

Many of the locations of tree squirrel populations in Portland included such grounds as city parks, golf courses and cemeteries. Table I (see Appendix A) describes the locations of tree squirrel populations found in this study. Some of the environmental and ecological conditions at each site are noted.

As different populations of tree squirrels were located, certain common factors in their habitats became apparent. Each species of squirrel will be discussed individually in an effort to show some of the common parameters of habitat shared by distinct populations.

Tamiasciurus douglasii douglasii

Nearly all sightings of this species occurred in southwest Portland; one sighting was made in the Forest Park area of northwest Portland. This species was often difficult to observe because of its dark color, relatively small size, and its tendency to stay in large trees with dense canopies such as Douglas-fir, cherry, big-leaf maple and Oregon white oak. During the warmer months there was always lush underbrush present, consisting of such plants as English ivy, blackberry, and grape. When my observations were begun, in

winter, it was not apparent that the dense vegetation which pine squirrels preferred would pose such a problem for future observations. Because of difficulties in observation as spring and summer progressed, study of pine squirrels was discontinued.

Pine squirrels also showed a strong preference for areas with a creek, often with steeply sloping sides, nearby. Figure 2 shows a sketch of a typical woodlot used by pine squirrels and which depicts the above characteristics. Pine squirrels often occurred in woodlots of relatively small sizes. One such woodlot was less than a city block square and bounded on all sides by busy streets or residential housing. In residental areas, pine squirrels are frequently seen by the residents, and are often known to use the same pathways in their daily movements. These pathways may include fence rows and electrical wires over streets (Bailey, 1936).

Sciurus niger rufiventer

Although they are not native to Oregon, western fox squirrels were the most frequently observed tree squirrels in the city. There were also more discrete populations of them, distributed more evenly throughout the city, than there were of the other two species of diurnal tree squirrels. Fox squirrels were first observed in Oregon in 1956 (Bob Maben, Oregon Department of Fish and Wildlife, pers. comm.). This species has radiated from its introduction at Salem,

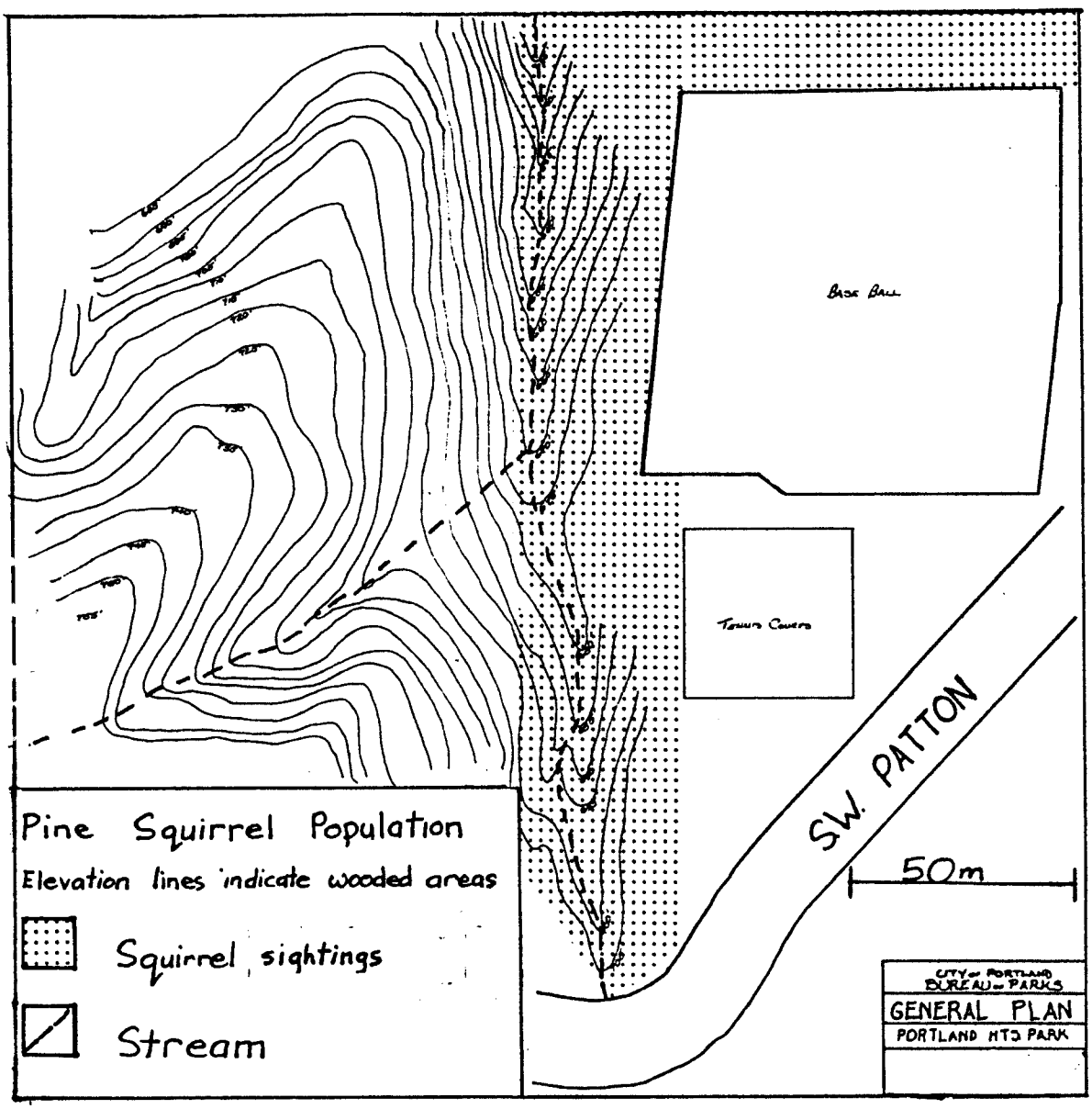

Figure 2. Pine squirrel population at Portland Heights Park.

Oregon and seems to thrive in urban environments. As will be noted later, in some cases it is probable that a close association between humans and urban fox squirrels is vital to the squirrels' existence at their present numbers.

The largest continuous area which fox squirrels occupy is in southeast Portland, and consists of Eastmoreland Golf Course, the Rhododendron Gardens, Reed College, Woodstock Park, and nearby residential areas.

There are few generalities apparent in habitats utilized by fox squirrels. Some populations exist in densely vegetated areas such as those preferred by pine squirrels. Other populations are content with a city block park containing few or no mast trees. Fox squirrels seem to be able to do without bodies of drinking water in close proximity to their habitat. Allen (1943) stated that fox squirrels are able to survive far from any open water by eating succulent plants in the summer. Many of these foods are buds, seeds, and fruits of plants introduced in parks for their aesthetic value. Also many of the fox squirrel populations are near areas with lawns which are frequently watered during the dry portions of the year.

Sciurus griseus griseus

I found only one individual in the study area. It lived in a part of Mt. Tabor Park (Figure 3) which was relatively free from road traffic. The area in which the squirrel was seen to range was about 4-5 acres of mowed lawn

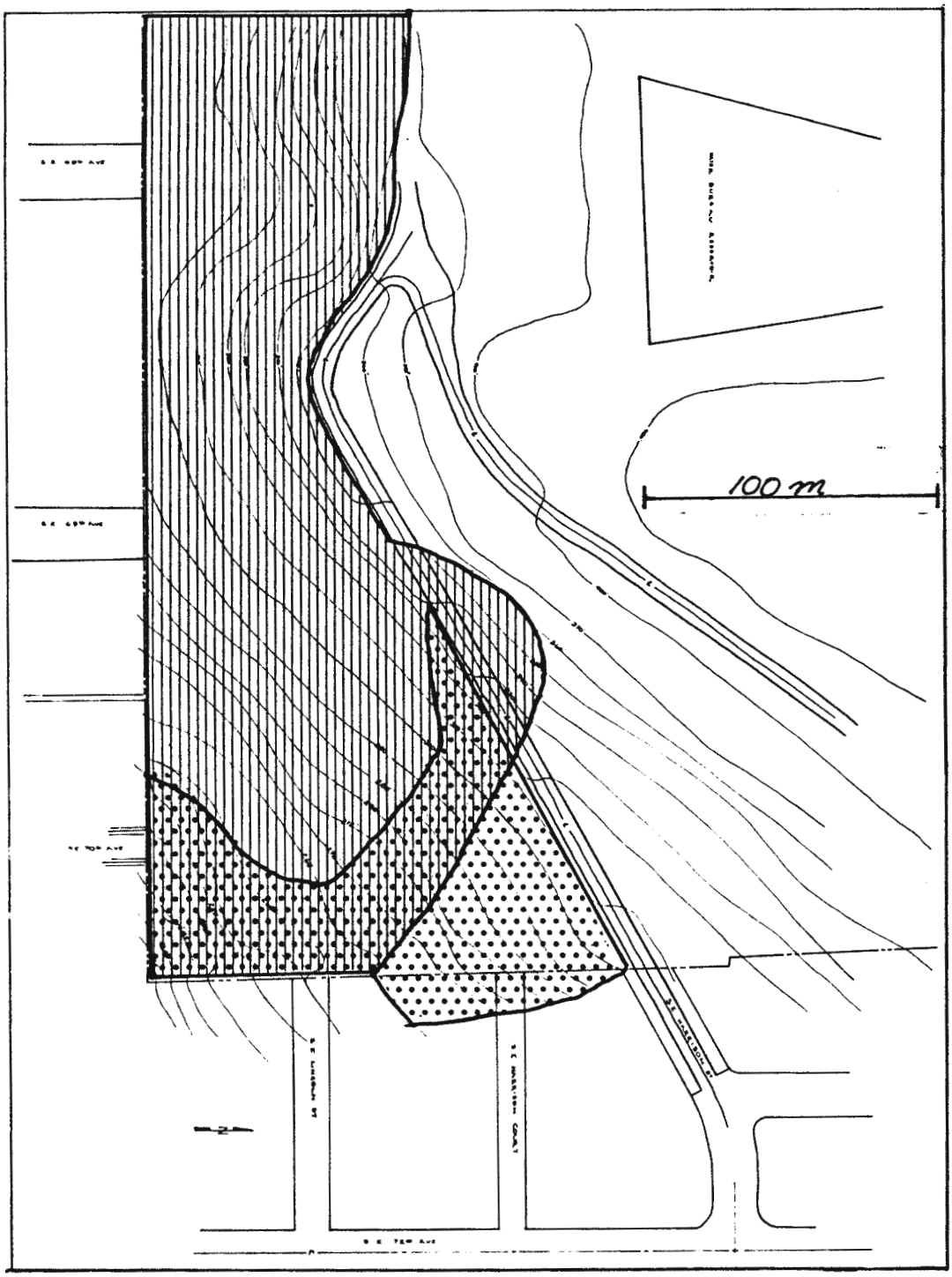

Figure 3. Mixed fox/western gray squirrel population at Mt. Tabor. Vertical hash marks indicate areas of western gray squirrel sightings; dotted areas indicate fox squirrel sightings.

with scattered Douglas fir, horse chestnut, bigleaf maple, oaks, black walnut, and filbert trees. An open water reservoir was also present in the area.

The Tigard population, outside the study area, lived in a secluded residential area located next to a filbert orchard. Douglas fir, bigleaf maple, filbert, and American chestnut were the major tree species of the area. There was a pond about 1 km from the area of greatest squirrel activity. The population was estimated at 8-10 western gray squirrels and 2-3 fox squirrels.

The common parameters of the Mt. Tabor Park and Tigard populations include presence of significant numbers of mast trees, relative seclusion from human activity and noise, a large body of water in close proximity, and the presence of the two species of tree squirrels.

I observed interspecific aggression and competition between fox squirrels and western gray squirrels at two sites: Mt. Tabor and Tigard. At Mt. Tabor on May 10, 1976 a gray squirrel making runs to and from a group of black walnut trees and burying nuts, was attacked by a fox squirrel which had been feeding in another part of the park. The gray squirrel successfully fended off the attacker. This was the only interaction observed between the two species at the Mt. Tabor site. However, at Tigard numerous instances of competition between fox and western gray squirrels were observed. The aggression was directed by the gray squirrels

toward the fox squirrels, usually during times of feeding. The gray squirrels seemed to tolerate visual contact of the fox squirrels and it was not until members of the two species came within 3-4 m of each other that aggression was displayed by the gray squirrels. Aggression usually took the form of a short dash toward the fox squirrel and always resulted in the fox squirrel retreating. No physical contact was ever observed between the two species. Similar interspecific aggression has been noted by Flyger (1955), Horwich (1972), and Layne (1954).

Although both the Tigard and Mt. Tabor populations had an abundant food supply, the proportions of the two species of squirrels differed markedly; by visual count, the proportion of gray squirrels to fox squirrels at Mt. Tabor was 1:3, but at Tigard it was 3:1.

Competition and/or aggression was also noted between Portland's tree squirrels and other genera of animals. The species which antagonized tree squirrels the most was Stellar's jay (*Cyanocitta stelleri*). Often jays swooped down upon squirrels which were feeding. Upon such an attack the squirrel would retreat to trees. The squirrels had the same reaction whenever a crow (*Corvus brachyrhynchos*) would call nearby or fly overhead. Steller's jays and tree squirrels use some of the same foods, notably filberts and acorns. I never observed crows to be aggressive to tree squirrels. One case was reported to me of racoons (*Procyon lotor*)

driving a group of squirrels from their nest located in a group of vines and then taking up residence there themselves.

I did not observe evidence of disease in tree squirrels. However, grounds crew workers and local residents at several study sites reported seeing squirrels that appeared weak, wobbly and with unhealthy-looking coats. Scabies is the disease most often found to infect tree squirrels (Allen, 1943; Flyger, 1955). The incidence of this disease, caused by the scabies mite (*Sarcoptes scabiei*) burrowing into the skin, usually rises when the resistance of the squirrels is low, often under conditions of high number and low food supply (Allen, 1943).

Accidental mortality due to natural causes was not found to be significant. I received several reports of accidental falls taken by tree squirrels as they were engaged in their aerobatics. There was no evidence that these squirrels sustained serious injuries as a direct result of the falls. Allen (1943) has reported squirrels falling up to 21 m without apparent injury.

I found no evidence that weather produces significant mortality directly or indirectly among Portland's tree squirrels. The city's heavy winter and spring rains ensure fall mast production and, therefore, winter food supply. The occasional sub-freezing temperatures to which the area is exposed have little, if any, effect on the health of tree

squirrels, which are able to find ample protection from the cold in their insulated dens and nests (Allen, 1943; Cross, 1942). Because the ground rarely freezes for more than a few days at a time, tree squirrels are able to dig up sufficient quantities of food even during the winter. I received no reports of malnourished or starving squirrels. If starvation does occur, it would probably be related to overpopulation which, according to verbal reports, occurs cyclically.

My observations indicate that in Portland, man is often a direct source of harassment and mortality of tree squirrels. I observed youths throwing objects at the animals and shooting them. I also saw several tree squirrels which had died due to injuries incurred when struck by automobiles. Numerous reports of road-kills were conveyed to me by other people. Although no figures are available, I am certain that automobiles contribute more significantly to tree squirrel mortality than does any other factor. Ingles (1947) wrote that western gray squirrels in California showed no visible fear of automobiles and, as a result, more squirrels died as road kills than from predation.

Predation is the next largest cause of mortality of tree squirrels in Portland. This source of mortality is indirectly related to man. In the wild in Oregon, the important predators of tree squirrels are the fisher (*Martes pennanti*); the marten (*Martes americana*), the red fox (*Vulpes fulva*), and several species of hawks (*Accipitridae*) and owls

(*Strigidae*) (Ingles, 1947; Ingles, 1965). However, except for a few hawks and owls, these predators are not known to occur in Portland. Man, however, has supplied predators in the form of domestic pets, notably, dogs (*Canis familiaris*) and house cats (*Felis catus*). I observed numerous cases of dogs chasing squirrels, but the alert squirrels easily managed to run to trees and climb to safety. Once out of the snapping range of the dog, the squirrel would often stop, turn around and face its aggressor, and bark back at the canine. This only served to antagonize the dog which tried even harder to jump at the squirrel. I have never seen a dog successfully catch a tree squirrel and only one case was reported to me of this occurring. The account relayed to me was that a fox squirrel fell from a tree and, while it lay stunned, a dog pounced upon it and killed it. I did not observe any cats stalking or killing squirrels. However, several people told me of cats they owned or knew which had successfully caught squirrels. It seems certain cats kill some squirrels, particularly young ones.

Noise produced by man was noted to affect squirrel behavior. Squirrel behavior was dependent not only upon the quantity but also the quality of noise. The sciurids seemed to ignore certain levels and types of background noise. The characteristics of the background noise varied between locations of populations depending upon vehicular traffic, industry, and construction in the area. On one occasion I

observed the western gray squirrel of Mt. Tabor lie in one position on a limb for 2 hours while a power saw was being used nearby. The same squirrel was often observed to leave the ground level when the noise from an airplane passing overhead or from a loud truck would reach it. At Pier Park I observed that when people in the park were vocalizing in loud tones that squirrel activity was often repressed.

Closely associated with noise in urban environments is human activity. Just as background levels of noise were ignored, so were certain forms and levels of human activity. For example, at golf courses the activity of golfers did not normally disturb fox squirrels. In the case of human vocalizations at Pier Park, such noise was usually accompanied by increased human activity, so it would be difficult to evaluate the effect of the two parameters independently of each other. In observing fox squirrels and western gray squirrels, I did note one difference in the reactions of the two species to being watched. It was my practice to remain as quiet and as motionless as possible when observing these rodents in an effort to keep my presence from being detected by them. This was not always possible and I could usually sense when a squirrel became aware of my presence. A fox squirrel, upon seeing me would either continue the activity in which it was engaged or leave the area quietly. In contrast, the western gray squirrel, upon realizing that it was under my observation, would seemingly become dis-

turbed and begin to bark and chatter loudly at me. After a few minutes of this behavior the western gray squirrels would ascend a tree and disappear in the foliage, all the while barking and chattering.

My observations indicate that tree squirrels have been adversely affected by the use of pesticides in the Portland area. Flyger (1974) has studied the tree squirrel population of College Park, Maryland to determine if they make suitable indicators of environmental quality. Flyger concluded that tree squirrels would not make good environmental indicators since they feed predominantly on nuts, seeds and buds and would, therefore, not be exposed to significant amounts of environmental pollutants or pesticides. However, I received reports of at least two instances where the use of pesticides was followed by a noticeable reduction of squirrel populations in the area of the sprayings. If the chemicals used did not result in the death of the squirrels, then in some way the contaminants or activity rendered the area unsuitable for squirrel occupation.

Behavioral Study

Table II (see Appendix A) summarizes the data acquired on fox squirrels at Pier Park (Figure 4). Of the seven squirrels marked, two were not seen again. Of the five squirrels subsequently seen, four were retrapped at the end of the study.

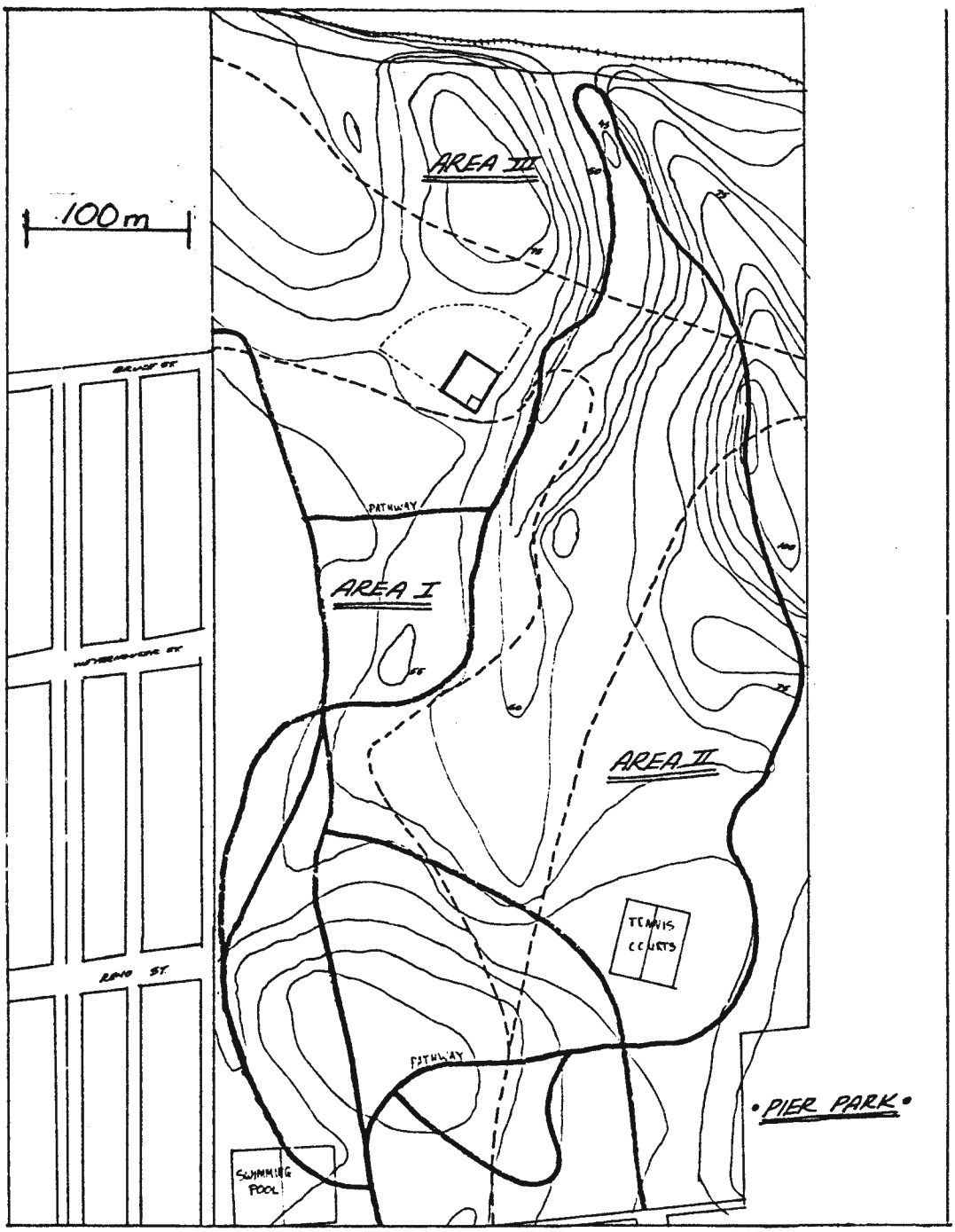

Figure 4. Fox squirrel population at Pier Park. Bold dashed lines delineate feeding areas. Bold solid lines designate pathways. Areas in the park not included in the feeding areas are predominately unwooded.

Although I did not observe pine squirrels long enough to learn much of their feeding behavior, many of Layne's (1954) observations on the feeding behavior of red squirrels (*Tamiasciurus hudsonicus*) seemed to hold true for the pine squirrels I observed. Similarly, Horwich's (1972) descriptions of feeding mannerisms and postures of gray squirrels seemed applicable to the two species of *Sciurus* in my study. Fox and western gray squirrels both at Pier Park and in Tigard usually began to feed soon after first light of day. The single western gray squirrel seen at Mt. Tabor usually began feeding two or three hours following sunrise. The actual time of the first feedings varied with the weather conditions. Parker (1952) found that temperatures above 90°F and below 45°F reduced squirrel activity significantly. Also, low temperatures accompanied by high velocity winds limited fox squirrel activity. Hicks (1940) found that precipitation of any kind tended to decrease activity of fox squirrels. These observations seem to be in general agreement with mine in Portland.

The Tigard population appeared to have two peaks in feeding activity on most days. The first peak came in the early morning during the first three hours following sunrise and the second peak came about one hour before dusk. Pier Park squirrels seemed to have a single peak in feeding activity corresponding to the same period of time as the morning peak of the Tigard population. In both populations

it was common to see individual squirrels feeding at any time between dawn and dusk. The Mt. Tabor western gray squirrel was never observed to feed immediately before dusk.

In the early mornings, people residing near Pier Park habitually strolled through the park and fed the squirrels. Observation of the collared squirrels revealed that a given squirrel habitually used the same feeding station in the park. There appeared to be three different areas used by three distinct groups of squirrels (see Figure 3). Each of the feeding areas had 2-3 feeding stations located therein. The sites classified as feeding stations were usually groups of trees on or near trees which squirrels habitually waited for handouts from people. All of the collared squirrels were from the same feeding area. None of the collared squirrels were ever seen to be feeding in either of the other two areas. It is possible that the feeding area of each squirrel is determined by the location of its den or nest.

Most squirrels obtained the majority of their food by foraging on the ground or feeding directly from trees. However, in Pier Park the situation was unique since the chief foods - English walnuts and peanuts - appeared to be supplied by humans. There were no walnut trees in the park. It is doubtful whether the large squirrel population at Pier Park could maintain itself on the natural foods that are present on the grounds should humans cease to provide

food.

Tables IIIA, IIIB, and IIIC show the types of food eaten by three of the squirrel populations studied. Observations suggest that food discrimination is learned by young squirrels. Juvenile squirrels were seen to pick up various inedible objects, mouth them, and promptly drop them. I presented the squirrels with different types and sizes of nuts, but could only conclude that squirrels preferred nuts which were not so large as to be difficult to carry in their mouths.

Although tree squirrels are not known to have highly socialized populations, some of their acitivites are socially oriented (Shorten, 1954; Terrill, 1941; Horwich, 1972). One such activity is their feeding. Cross (1942) noted that as squirrels began feeding in the mornings, 6-8 squirrels might feed in a single tree. This behavior was also observed among the fox and western gray squirrels of the Portland area. Squirrels were also noted to feed in groups on the ground. This behavior is thought to provide for better protection of the group as a whole since an alarm call from a single squirrel would send the whole group to the safety of the trees (Shorten, 1954).

Intraspecific competition during social feeding was never observed. Flyger (1955) found no social strife among squirrel populations experimentally kept at densities as high as 50 squirrels/10 acres. However, Flyger also noted

that strife was evident among squirrels when a concentrated food supply was placed in a small area. This behavior was noticed among the squirrels of Pier Park.

A noticeable difference was seen between the two species at Mt. Tabor concerning their nut burying behavior. The western gray squirrel was seen to bury nuts from March 1976 until May 1976. These nuts were black walnuts produced in the fall of 1975. The fox squirrels were not seen to bury any nuts during the same period. The timing of the burying behavior displayed by the western gray squirrel seems unusual since squirrels generally dig up nuts and eat them during that period of time (Allen, 1943; Stienbecker and Browning, 1970).

I observed the fox squirrels of Pier Park to strip the bark from bigleaf maple trees during late spring and early summer. The bark was usually stripped from green limbs and stems and the moist cambium lining the inside of the strips was scraped off and eaten. This habit of tree squirrels has been recorded nearly everywhere they are found (Ingles, 1947; Allen, 1943; Middleton, 1931; Fritz, 1932).

Pine squirrels and red squirrels are well known for their territorial behavior (Layne, 1954; Smith, 1968). However, the larger tree squirrels are not known to be territorial (Allen, 1943; Flyger, 1955). The only behavior I observed which might be considered territorial was the single

occurrence of a fox squirrel attacking a gray squirrel while both were feeding.

Mating behavior has been described for pine squirrels by Layne (1954) and for the larger tree squirrels by Parker (1952) and Horwich (1972). Although several mating chases were observed, I saw only one act of copulation; that involving fox squirrels at Pier Park on May 29, 1976. Mating chases involved from 3-6 individuals.

I observed dominance relationships among fox and western gray squirrels both intraspecifically and interspecially. These relationships were manifested in chases of "intolerance" (Flyger, 1955) between two squirrels as between the western gray and fox squirrels at Tigard. Dominance was also displayed among the fox squirrels at Pier Park when individuals which found concentrated food supplies in small areas were able to chase subordinate squirrels away from the area. Adult squirrels were higher ranking than juvenile squirrels (Flyger, 1955). It is not clear what factors are involved in dominance relationships of *Sciurus*. One reason for this is that it is often difficult to distinguish dominance behavior from play in which the "aggressor" may alternate between two or more individuals.

DISCUSSION

Previous mention has been made to the "preferred habitat" of tree squirrels. In rural environments, references to preferred habitat of squirrels imply the type of vegetation, topography, and climate of the areas in which a given species is seen most often. If animal species native to rural environments are able to modify their natural behavior in ways peculiar to urban life, factors other than those present in natural environments become important in selection of habitat. What man has done, in effect, is to create an artificial environment with a new set of parameters to which individual species must adapt in order to successfully propagate themselves. Thus, anthropogenic factors must be considered in order to understand the effect of an urban setting on wildlife populations.

The most obvious signs of human presence in urban environments are buildings, streets, and parking areas. In Portland such structures are usually of relatively recent (last 100 years) origin, and have largely replaced the wooded areas once suitable for native tree squirrels. A consequence of clearing and building has been loss of food resources and nesting and denning sites for the squirrels (Hattan, 1976).

Although there seem to be no records of a western gray

squirrel population in Portland in the past, it is generally thought that these squirrels occupied most of the Portland area which was conifer-oak woodland (Chet Kebbe, Oregon Department of Fish and Wildlife, pers. comm). If this is true, then numbers of western gray squirrels in Portland have surely decreased. One possible explanation is that the conifer-oak woodland preferred by these squirrels (Hattan, 1976) has been removed, or altered in ways which makes it unsuitable as a habitat for that species.

Another anthropogenic factor affecting tree squirrels is clearing of wooded areas and building of various structures. Such human activities affect not only food and cover available to tree squirrels, but also the ability of squirrels to move from place to place. Gill and Bonnett (1973) used the term "green strip" to refer to wooded corridors extending from locations within cities where terrestrial wildlife populations existed, to the green belt on the city's perimeter. Such green strips should be maintained and kept continuous with the absence of ecological barriers (*e.g.*, business, industrial, or residential areas lacking mature trees) which would restrict squirrel movement. The existence of a green strip in the Reed College/Westmoreland Golf Course area helps to account for the large fox squirrel population in that part of Portland. With the absence of ecological barriers, this population has extended its range until such barriers were encountered.

Fox squirrels may be easily seen in the areas located in the green strip, but as one moves away from it into residential areas, numbers of squirrels seen diminish rapidly.

The reason it is vitally important not to restrict movement of these terrestrial animals is so that genetic isolation will not occur. Gill and Bonnett (1973) argued strongly against city planning that allows mammal populations to establish themselves within a city and then become sealed off from other wildlife stocks because the corridors by which the animals penetrated the city become blocked. Baldwin (1969) studied squirrel populations in isolated wooded sections in urban communities and demonstrated that the aberrant coats which such populations often possess are due to genetic drift. Genetic isolation has probably occurred in many of Portland's squirrel populations; it remains to be seen what will happen in these isolated populations in the future.

In addition to removing native plant species from areas, man has also introduced plant species into the urban landscape. This practice is not necessarily detrimental to urban squirrels because many introduced plant species are potential sources of food and shelter. The ability of tree squirrels to adapt their feeding habits to include introduced varieties of plants is certainly advantageous to the animals' survival in cities. Such food sources in Portland include English walnuts, black walnuts,

filberts, horse chestnuts, and American chestnuts. Also the buds, seeds and fruits from these and a variety of other introduced plant species may be eaten by Portland's diurnal tree squirrels. Fox squirrels are apparently very adaptable to new foods and environments, since upon being introduced into Oregon they have proliferated, frequently feeding on plant species not found in their natural range.

Anthropogenic factors other than those affecting natural topography and vegetation are also important in affecting selection of habitat by tree squirrels.

Some residential and park areas of Portland still include habitat suitable for native tree squirrels in that there are food sources, water supplies, and denning and nesting sites available. However, even though these physical necessities remain, other conditions of the area may render it unsuitable for tree squirrel occupation. Such conditions already mentioned are the presence of unacceptable levels of noise and chemical pollution, and intolerable human activity. My observations indicate that of the three diurnal species of tree squirrels in Portland, the western gray squirrel is the least adaptable to the above conditions. This species seems limited to secluded areas with low noise levels and limited human activity, and seems sensitive even to being observed.

The lack of natural predators of tree squirrels in Portland has been filled by the presence of other selective

pressures such as automobiles and domestic pets. Tree squirrels which adapt their behavior to avoid vehicular traffic presumably have an advantage over squirrels which do not do so. Beatty (1932) attributed a reduction in numbers of roadkills of western gray squirrels in California to the squirrels learning how to avoid automobiles. It is probable that Portland's urban squirrels develop a similar wariness for street traffic. This wariness could result in learning how to avoid automobiles at the ground level or in using alternate paths such as overhead electrical wires to cross streets.

Another aspect of Portland's urban tree squirrel population which should be discussed is the extent to which their aesthetic value is appreciated by people. It is evident that the residents of the Pier Park community are quite concerned about the welfare of the squirrel population in that area. Yet, those same squirrels are annually responsible for hundreds of dollars worth of damage to the trees in the park. The major economic impact of Portland's tree squirrel population to the city is the money which must be spent to cut away dead or injured plant growth resulting from the squirrels' habit of stripping the bark from around tree trunks and limbs. Until now, few, if any, complaints have been voiced against this expenditure of city finances. Acceptance of this monetary loss will continue as long as the animals are not considered pests and

people continue to appreciate or at least tolerate their presence. Conversely, one could ask to what lengths the people of Portland are willing to go in order to protect the welfare of tree squirrels, rather than merely tolerate their presence. Such lengths might include such things as city planning which would maintain or re-establish green strips, passing and/or enforcing city regulations prohibiting or restricting the number of free roaming dogs and cats, and providing alternate paths by which squirrels could pass over busy streets in areas habitually used for crossings. Such considerations have many social, political, and economical ramifications.

CONCLUSIONS AND RECOMMENDATIONS

1. Where western gray and fox squirrels coexist, either species may dominate the other. It is probable that the dominance depends on population numbers in any given habitat, with the more abundant species dominating the other.

2. Western gray squirrels' native habitat is hardwood or mixed hardwood/conifer woodland. This type of woodland is scarce within Portland. The disappearance of the western gray squirrel from Portland's urban landscape seemingly cannot be attributed to the superior aggressiveness of the fox squirrel. Rather, the scarcity of the western gray squirrel in the Portland area appears to be linked to the destruction or alteration of its preferred habitat.

3. Most of the fox squirrel populations in Portland are not found in hardwood or mixed hardwood/conifer woodland, but seem to prefer a parklike setting.

4. Of the two species, the fox squirrel seems to display a higher degree of adaptability to urban environments than does the gray squirrel.

5. The pine squirrel appears to be successful in urban environments. It is able to live in the more densely vegetated, hilly forest areas of the city.

6. In city parks where tree squirrels are frequently fed, individual squirrels may habitually use the same feeding area. This could result in a division of feeding areas used by distinct groups of squirrels. It is possible that the feeding area to which individual squirrels belong is determined by the location of their nest or den.

7. If a study is planned in a residential area and animals are to be handled in any way, a public relations campaign should be conducted in order to inform the residents of exactly what is being done. If complaints result from the campaign, the study may be aborted or altered before a significant amount of work has been invested in it. Also, care should be taken with any field equipment because such items notoriously disappear if left unattended.

8. If urban research calls for marking of individuals, one should use a method of marking which does not require recapture of the individuals for removal of the apparatus.

9. Since man has altered the habitat of native squirrel species and introduced other species into unfamiliar territory, he has assumed the responsibility of studying these animals to determine how they are affected by these changes in environment. It is only by such research that information might be obtained which could prove vital to the existence of such species in the future.

REFERENCES

Literature Cited

Allen, Durward L. 1943. Michigan fox squirrel management. Michigan Department of Conservation, Game Division Publication 100:1-404.

Allison, R. 1953. North Carolina gray squirrel investigations. Wildl. Resource Commission. Raleigh.

Anonyomous. 1976. Local climatological data: Annual summary with comparative data, 1976, Portland, Oregon. National Oceanic and Atmospheric Administration Environmental Data Service/National Climatic Center, Ashville.

Bailey, Vernon. 1936. The mammals and life zones of Oregon. North American Fauna, No. 55.

Baldwin, F. T., Jr. 1969. The white squirrels of Chickahominy Park. Virginia Wildl. 30(4): 103-108.

Baumgartner, L. L. 1940. The fox squirrel: Its life history, habits, and management in Ohio. Unpub. Ph.D Thesis, Ohio State Univ., Columbus

Beatty, M. E. 1932. California gray squirrel. Yosemite Nature Notes, 11(11): 5-6.

Brenneman, W. S. 1954. Tree damage by squirrels: Sylviculturally significant? J. Forestry, 52(8): 604.

Cox, P. 1970. The squirrels of Queen's Park and Philosphers Walk. Department of Zoology, Univ. of Toronto, Toronto.

Cross, R. H., Jr. 1942. A Study of the habits and management of the gray squirrel in Virginia. Unpub. M.S. Thesis, Virginia Polytechnic Institute, Blacksburg.

Cross, Stephen P. (Unpub.). Telemetry as a technique in the study of western gray squirrel behavior.

Flyger, V. 1955. Implications of social behavior in gray squirrel management. Trans. N. Amer. Wildl. Conf. 20, 381-389.

_____. 1974. Tree squirrels in urbanizing environments, p. 121-123. In J. H. Noyes, (ed.), Wildlife in an urbanizing environment. Coop. Ext. Ser. U. S. Department of Agri. and County Ext. Ser. Cooperating. Univ. of Massachusetts, Amherst.

Fritz, Emanuel. 1932. Squirrel damage to young redwood trees. J. of Mamm., 13(1): 76.

Gill, D. and P. Bonnett. 1973. Nature in the urban landscape, a study of city ecosystems. New York Press, Baltimore.

Hathaway, M. B. 1973. Ecology of city squirrels. Nat. Hist., 82(9): 61-62.

Hattan, Greg. 1976. Oregon's gray squirrels. Oregon Wildl., 31(11): 6-7.

Hicks, E. A. 1942. Some major factors affecting the use of two inventory methods applicable to the western fox squirrel, *Sciurus niger rufiventer* (Geoffroy). Iowa State College J. Sci. 16: 299-305.

Horwich, Robert H. 1972. The ontogeny of social behavior in the gray squirrel (*Sciurus carolinensis*). Berlin, Saladruck, 1 Berlin 36.

Ingles, L. G. 1947. Ecology and life history of the California gray squirrel. Calif. Fish and Game, 33(3): 139-158.

_____. 1965. Mammals of the Pacific States. Stanford Univ. Press, Stanford.

Irving, Frank D., and James R. Beer. 1963. A six-year record of sugar maple bark stripping by gray squirrels in a Minnesota oak-maple stand. J. Forest., 61(7): 508-511.

Kilham, L. 1954. Territorial behavior of red squirrel. J. Mamm., 35(2): 252-253.

Layne, J. N. 1954. The biology of the red squirrel *Tamaisciurus hudsonicus loguax* (Bangs), in central New York. Ecol. Monog., 24: 227-267.

Liscinsky, S. A. 1951. The life history and habitat of the northern gray squirrel in relation to some plant communities in Centre County, Pennsylvania. Unpub. M.S. Thesis, Pennsylvania State Univ., University Park.

McKeever, S. 1964. Food habits of the pine squirrel in northeastern California. J. Wildl. Mgt., 28(2): 402-403.

Middleton, A. D. 1931. The grey squirrel: the introduction and spread of the American gray squirrel in the British Isles, its habits, food and relations with the native fauna of the country. Sidewick & Jackson, Ltd., London.

Montgomery, R. D. 1941. Population studies and habitat improvement for southern Michigan fox squirrels. Michigan Dept. Cons., Game Div., Pittman-Robertson Proj. 8R, 1st Ann. Prog. Rept. (Unpub.) Jan. 1, 1941: 1-85.

Parker, Richard L. 1952. Ecology and economics of the western fox squirrel, *Sciurus niger rufiventer* (Geoffroy), in Payne County, Oklahoma. Unpub. Thesis, Oklahoma Agricultural and Mechanical College, Stillwater.

Shorten, M. 1954. Squirrels. Collins, London.

Smith, C. C. 1968. The adaptive nature of social organization in the genus of tree squirrels *Tamiasciurus*. Ecol. Monog. 38: 31-63.

Stienecker, W. and Browning, B. M. 1970. Food habits of the western gray squirrel, Calif. Fish and Game 56(1): 36-48.

Stienbecker, W. 1977. Supplemental data on the food habits of the western gray squirrel. Calif. Fish and Game, 63(1): 11-21.

Terrill, H. V. 1941. A preliminary study of the western fox squirrel (*Sciurus niger rufiventer* [Geoffroy]), in Missouri. (Unpub. M.A. Thesis) Univ. Missouri, Columbia.

Trimble, Donald E. 1963. Geology of Portland, Oregon and adjacent Areas. Geological Survey Bulletin No. 1119. United States Government Printing Office, Washington, D. C.

Yeager, Lee E. 1936. Fox squirrel seriously damages elm tree. J. Mamm., 17: 417-418.

Other References

Allen, John M. 1952. Gray and fox squirrel management in Indiana. Indiana Department of Conservation, Public Relations Bull. No. 1: 1-112.

Anthony, H. E. 1928. Field book of North American mammals. G. P. Putnam's Sons, New York.

Baker, Rollin H. 1944. An ecological study of tree squirrels of eastern Texas. J. Mamm., 25: 18-24.

Bakken, A. A. 1952. Interrelationship of *Sciurus carolinensis* (Gmelin) and *Sciurus niger* (Linnaeus) in mixed populations. Unpub. Ph.D. Thesis, Univ. of Wisconsin, Madison.

Brown, Louis G. and Lee E. Yeager. 1945. Fox squirrels and gray squirrels in Illinois. Ill. Nat. Hist. Bull. 23: 449-536.

Doeble, John H. 1967. Home range and activity of the gray squirrel in a southwest Virginia woodlot. Unpub. M.S. Thesis, Virginia Polytechnic Institute, Blacksburg.

Flyger, V. F. 1951. Bibliography of the tree squirrels and other pertinent literature. Pennsylvania Cooperative Wildl. Research Unit, Quarterly Report, 13(4): 19-38.

_____. 1956. The social behavior and population of the gray squirrel (*Sciurus carolinensis* Gmelin) in Maryland. Unpub. Ph.D. Thesis, School of Hygiene and Public Health of Johns Hopkins Univ., Baltimore.

_____. 1959. A comparison of methods for estimating squirrel populations. J. Wildl. Mgt. 23(2): 220-223.

_____. 1961. Southeastern Association of Game and Fish Commissioners. Symposium on the gray squirrel. Contrib. 162. Maryland Department of Research and Education.

Goodrum, Phil. 1940. A population study of the gray squirrel in eastern Texas. Texas Agr. Exp. Station Bull. 591: 5-34.

Gordon, Kenneth. 1936. Territorial Behavior and Social Dominance Among Squirrels. J. Mamm. 17(2): 171.

Graham, Edward and Jacob Uhrich. 1943. Animal parasites of the fox squirrel, *Sciurus niger rufiventer*, in southeastern Kansas. J. Parasit. 29: 159-160.

Grinnell, J. and J. S. Dixon and J. M. Linsdale. 1937. Fur-bearing Mammals of California, Vols. I and II. Univ. of Calif. Press, Berkeley.

Hartman, George P. 1940. Life history and management of fox squirrels, with particular reference to the western race, *Sciurus niger rufiventer*. Unpub. M.S. Thesis, Univ. of Michigan, Ann Arbor.

Hicks, Ellis A. Ecological factors affecting the activity of the western fox squirrel, *Sciurus niger rufiventer*. Ecol. Monog., 19(4): 287-302.

Hunt, George S. 1950. Some methods of censusing fox squirrels, *Sciurus niger rufiventer* (Geoffroy). Unpub. M.S. Thesis, Univ. of Michigan.

Hungerford, K. E. and N. G. Wilder. 1941. Observations on the homing behavior of the gray squirrel (*Sciurus carolinensis*). J. Wildl. Mgt. 5: 458-460.

Johnson, Morris D. 1957. Movements, recapture frequencies and duration of residence of fox squirrels released in a new habitat. Unpub. M.A. Thesis, Univ. of Missouri, Columbia.

Kilham, Lawrence. 1954. Territorial behavior of red squirrels. J. Mamm., 35(2): 252-253.

Linduska, J. P. 1942. A new technique for marking fox squirrels. J. Wildl. Mgt., 6(1): 93-94.

Moore, Joseph Curtis. 1959. Relationships among living squirrels of the Sciurinae. Bull. Amer. Mus. Nat. Vol. 118: 153-206.

Pack, J. C. 1966. Influence of the social hierarchy on Gray Squirrel behavior. Unpublished M.S. Thesis, Virginia Polytechnic Institute, Blacksburg.

APPENDIX A

ACCUMULATED DATA FROM FIELD STUDIES

TABLE I

SUMMARIZATION OF LOCATIONS AND ENVIRONMENTAL CONDITIONS OF SQUIRREL SIGHTINGS

Location of site and Squirrel species seen	Date, time of day and Weather conditions of Sighting	Topography of the area	Remarks
T. douglasii (1) Vacant lot between S.W. 7th Ave. and Caldrew Dr.	3-25-76; 2:30 PM: Sunny; T: 50°; W.S: S; BP: 30.06; RH: 60%.	Thickly wooded area w/ dense underbrush. East & west parts of lot steeply sloping together to form a deep valley. Lot bounded on two sides by busy streets and two sides by residential areas. A small stream flowed through the middle of the valley.	Garbage and large metal containers were dumped in the area.
T. douglasii Gabriel Park: S.W. 45th Ave. between S.W. Multnomah Blvd. and S.W. Vermont.	Oct. 1976. No squirrels were seen by me here but a resident familiar with squirrel species in the area told me about pine squirrels in the area.	The north half of the park was flat, lawn area, w/ few and scattered trees. The south half of the park was somewhat hilly & well wooded with Douglas-fir and cedars. A small stream flowed east to west through the park center. The park was bounded by S.W. 45th Ave. on the west.	Many past road kills reported as squirrels tried to cross S.W. 45th. There were no nut trees in the park but several west of S.W. 45th. Park was well frequented by humans and a favorite place to exercise dogs. The area was relatively quiet.
T. douglasii Wooded area between S.W. Brugger & S.W. 56th to hills just S.W. of Smith Elementary School.	3-25-76. I saw no squirrels but a resident knowledgable about squirrels told me he had seen one in the area and heard several chattering in the trees.	The area was well wooded with Douglas-fir and some nut trees. The understory vegetation around Smith School was extremely dense. The terrain was flat and residential north of Garden Home Rd. and hilly and woody south of Garden Home Rd. A small stream flowed east to west just south of Smith School.	The area was not exposed to much traffic except across Garden Home Rd. A few roaming dogs and cats were seen.

TABLE I (continued)

Location of site and Squirrel species seen	Date, time of day and Weather conditions of Sighting	Topography of the area	Remarks
S. niger (2) Creston Park.	4-7-76; 10:30 AM; Overcast; T: 55°; WS: 3; BP: 29.74; RH: 57%.	Elevation gradually rising from west to east; a sink formed in northern extreme of park due to 30' drop in elevation; bordered by residential areas on west and south sides, a school on the east side, and a well travelled street on north side. No bodies of water present. Area lawned w/scattered trees.	Many park frequenters, especially children from adjoining school. Several free roaming dogs in the area. Observed one dog chase a squirrel up a tree. Noise level relatively high.
S. niger (2) Reed College Campus.	4-7-76; 1:00 PM; Sunny; T: 62°; WS: 13; BP: 29.70; RH: 42%.	Predominately flat lawned area w/scattered trees including black walnut. Well wooded in north portion of campus on both sides of Crystal Springs creek which ran east to west.	Campus setting relatively quiet but heavily traversed by students. Some free-roaming dogs seen.
S. niger Eastmoreland Golf Course & Rhododendron Gardens.	4-7-76; 2 PM; Sunny; T: 62°; WS: 14; BP: 29.68; RH: 42%.	Golf course mainly flat lawned area w/scattered trees. Gardens thickly vegetated w/rhododendron plants & a variety of trees. Bodies of water located throughout area.	Area relatively quiet but considerable human activity. Heavy vehicular traffic passing over one street running east and west through the center of the area Robins & crows numerous and active.

TABLE I (continued)

Location of site and Squirrel species seen	Date, time of day and Weather conditions of Sighting	Topography of the area	Remarks
S. niger (1) Sellwood Park.	4-9-76; 3 PM; Sunny; T: 65°; WS: 5; BP: 29.84; RH: 67%.	Gradually sloping lawned area; at extreme western boundary of park steeply sloping to river bed. Moderately scattered w/trees, especially Douglas fir. Willamette River flowing about 1 km to the west of park. Also a water pool in SE corner of park.	Observed an unleashed dog chasing a squirrel up a tree. Slight vehicular traffic. Quiet residential area. Many park frequenters. Several roaming dogs.
S. niger (3) S.E. Exter and St. Andrews, north of Waverly Country Club.	2-9-76; 11 AM; Sunny; T: 47°; WS: 4; BP: 30.01; RH: 68%.	Residential and golf course, lawned area. Many ornamental trees in residential area; Douglas-fir, maple, and oak trees scattered throughout golf course. Terrain flat. Western edge of golf course bordered Willamette River.	Slight automobile traffic, quiet residential area. Much bird activity. No roaming domestic pets observed.
S. niger (1) S.W. Murray St. and Murray Lane.	2-10-77; 2:30 PM; Sunny; T: 50°; WS: 4; BP: 30.29; RH: 54%.	Lawned park area w/many scattered ornamental trees gradually sloping terrain. City reservoir close by.	Considerable vehicular traffic bordering area. Relatively noisy. Many people around. Several roaming pets observed.
T. douglasii (1) Portland Hts. Park.	See narrative.	See narrative.	See narrative.
S. niger (20) Pier Park,	See narrative.	See narrative.	See narrative.

TABLE I (continued)

Location of site and Squirrel species seen	Date, time of day and Weather conditions of Sighting	Topography of the area	Remarks
S. niger (1) Chimney Park.	4-9-76; 11 AM; Sunny; T: 56°; WS: 5; BP: 29.84; RH: 67%.	Predominately cleared lawn area w/scattered trees. N.W. area of park sharply rising and thickly wooded w/dense understory. Columbia River flowing about 2 km to the west of park.	The park area bounded on all sides w/roads heavily used especially by commercial vehicles. Little human or other mammal activity noted.
S. niger (3) Columbia Park.	9-25-76; 9:30 AM; Sunny; T: 59°; WS: 0; BP: 29.88; RH: 90%.	Terrain flat, thinly wooded w/Douglas-fir & maple trees. Large play ground area. Bordered on all sides by streets. No body of water present.	Park located in a very populated residential area. Many park frequenters. Many free roaming dogs & cats. Very noisy from vehicular traffic & human vocalizations.
S. niger (6) Rose City Golf Course.	10-5-76; 11:30 AM; Sunny; T: 63°; WS: 6; BP: 30.15; RH: 56%.	Flat, grassy, lawned area. Trees scattered in clusters throughout park. Many oak trees. Pools of water standing in various places of the park. Bordered by residental areas.	Considerable human activity. Observed no free roaming domestic pets. Relatively quiet area.
S. niger(20) Lone Fir Cemetery.	4-5-76; 10:30 AM; Sunny; T: 53°; WS: 13; BP: 30.26; RH: 58%.	Flat terrain, grassy lawned area. Thinly wooded w/Douglas-fir, birch, maple, & willow trees. The area fenced in on all sides & bordered by residential streets. No bodies of water present.	Considerable bird activity among crows, jays, and robins. Limited mammal activity. Relatively low noise levels.

TABLE I (continued)

Location of site and Squirrel species seen	Date, time of day and Weather conditions of Sighting	Topography of the area	Remarks
S. niger (1) Laurelhurst Park.	4-5-76: 10:30 AM; Sunny; T: 53°; WS: 11; BP: 29.76; RH: 66%.	Predominately lawned grassy areas but well wooded along perimeter of the park. Main park area flat w/rising inclines on south & north boundaries. Sloping areas covered w/ivy. Paved pathways throughout park. Large duck pond in central eastern portion of park.	Many park frequenters; many free-roaming dogs; Heavy vehicular traffic on roads bordering south & east sides of park. Residential areas to the north & west. High noise levels due to traffic & vocalizations. Nest boxes had been placed in trees for squirrels.
S. niger (4) Lair Hill Park.	2-9-76; 10:30 AM; Overcast; T: 48°; WS: 4; BP: 39.01; RH: 68%.	Lawned area w/scattered Douglas-fir & walnut trees. A square city block, bordered on all sides by streets. Playground in the park. No bodies of water present.	Many children frequented the park. Heavy vehicular traffic on west boundary; residential areas on all other sides. Hurricane fence lining the west side. High noise levels. Numerous free-roaming dogs.
S. griseus (1) *S. niger* (3) Mt. Tabor Park S.E. 72nd and Lincoln.	See narrative.	See narrative.	See narrative.

TABLE I (continued)

Location of site and Squirrel species seen	Date, time of day and Weather conditions of Sighting	Topography of the area	Remarks
S. niger (1) Church grounds at S.E. 52nd & Duke.	4-9-76; 2 PM; Sunny; T: 65°; WS: 5; BP: 29.84; RH: 67%.	Terrain flat & well wooded w/Douglas-fir. Area between trees densely packed w/cabins. Area a square city block bounded by streets on all sides. A fence running around perimeter of grounds. No appreciable body of water present.	Area relatively quiet during most of year. Much human activity annually during three weeks in the summer. Fence protected grounds from free roaming dogs. Grounds keeper hand-fed squirrels. Reports given of children harassing squirrels.
S. niger (1) Woodstock Park.	4-17-76; 12 PM; Sunny; T: 46°; WS: 8; BP: 30.06; RH: 52%.	Lawned area sparsely wooded w/trees. Oak & Douglas-fir trees present. Terrain level & bounded on all sides by streets. No bodies of water present.	Area w/appreciable noise levels from vehicular traffic & vocalizations. Road traffic moderate. Park well frequented by humans. Several free roaming dogs present.
S. niger (2) Mt. Scott Park.	4-7-76; 11:30 AM; Sunny; T: 58°; WS: 13; BP: 29.71; RH: 47%.	Lawned area moderately wooded w/trees. Surface flat. Area bounded by streets. Small wading pool present.	Noise levels moderate. Heavy vehicular traffic along one side of park; residential areas along other sides. Considerable human utilization of park. No free roaming domestic pets seen.

T = Temperature in degrees Farenheit.
WS= Wind speed in knots per hour.
BP= Barometric pressure in inches.
RH= Relative humidity. Weather data courtesy of the U.S. Weather Bureau, Portland, Oregon.
Numbers in parentheses indicate numbers of individuals seen.

TABLE II

DATA FROM TRAPPING PROCEDURES

Color Code	Sex	Date Trapped	Weight*	Date Retrapped	Weight*
Blue	M	7-1-76	690g	--	--
Yellow	M	7-1-76	--	10-22-76	750g
Green	F	7-1-76	520g	--	--
Orange	M	7-2-76	730g	--	--
Red	F	7-8-76	620g	10-22-76	800g
Red/Orange	F**	7-8-76	800g	10- 2-76	700g
Blue/Orange	M	7-7-76	770g	10-22-76	800g

*Weights to the nearest 10g

**Lactating.

TABLE IIIA

FOOD ITEMS SEEN TO BE UTILIZED BY MT. TABOR POPULATION

Type of Food	Species	Seasons Available			
		Sp	S	F	W
Whole Nuts	*Juglans nigra*	x	x	x	x
	Quercus spp.		x	x	
	Aesculus hippocastanium		x	x	
	Corylus spp.		x	x	
Seeds	*Acer macrophylum*	x	x	x	x
	Pseudotsuga menziesii	x	x	x	x
	Unidentified	x	x	x	x
Buds	*Acer macrophylum*	x	x		
	Quercus spp.	x	x		
	Cornus nuttallii	x	x		
	Aesculus hippocastanium	x	x		
Mushrooms	Unidentified	x	x	x	x
Invertebrates	Unidentified	x	x	x	x

Sp = Spring; S = Summer; F = Fall; W = Winter.

TABLE IIIB

FOOD ITEMS SEEN TO BE UTILIZED BY PIER PARK POPULATION

Type of Food	Species	Seasons Available			
		Sp	S	F	W
Whole Nuts	*Juglans regia*	x	x	x	x
Legumes	*Arachis hypogaea*	x	x	x	x
Seeds	*Acer macrophylum*	x	x	x	x
	Pseudotsuga menziesii	x	x	x	x
	Unidentified				
Buds	*Acer macrophylum*	x	x		
	Pseudotsuga menziesii	x	x		
	Cornus nuttallii	x	x		
Bark	*Acer macrophyllum*				
Mushrooms	Unidentified	x	x	x	x
Invertebrates	Unidentified	x	x	x	x
Orange Peels					
Apple Cores					

Abbreviations as in Table IIIA.

TABLE IIIC

FOOD ITEMS SEEN TO BE UTILIZED BY TIGARD POPULATION

Type of Food	Species	Seasons Available			
		Sp	S	F	W
Whole nuts					
	Castanea dentata	x	x	x	x
	Corylus spp.	x	x	x	x
Seeds					
	Acer macrophylum	x	x	x	x
Buds					
	Acer macrophylum	x	x		
	Castanea dentata	x	x		
	Corylus spp.	x	x		
Grapes				x	
Mushrooms					
	Unidentified	x	x	x	x
Invertebrates					
	Unidentified	x	x	x	x

Abbreviations as in Table IIIA.

TABLE IV

PLANT SPECIES MENTIONED IN TEXT

Understory	
English ivy	*Hedera helix*
Grape	*Vitis* spp.
Oregon grape	*Berberis* spp.
Huckleberry	*Vaccinium* spp.
Blackberry	*Rubus* spp.
Nettles	*Urtica* spp.
Poison oak	*Rhus diversiloba*
Peanut	*Arachis hypogaeae*
Trees	
Douglas fir	*Pseudotsuga menziesii*
Western hemlock	*Tsuga heterophylla*
Western redcedar	*Thuja plicata*
Pacific dogwood	*Cornus nuttallii*
Bigleaf maple	*Acer macrophylum*
Oregon ash	*Fraxinus latifolia*
Red Alder	*Alnus ruber*
Cascara buckthorne	*Rhamnus purshiana*
Pacific mandrone	*Arbutus menziesii*
Oregon white oak	*Quercus garryana*
English walnut	*Juglans regia*
Black walnut	*Juglans nigra*
Filbert	*Corylus* spp.
Horse chestnut	*Aesculus hippocastanium*

Table IV (continued)

Trees (continued)	
American chestnut	*Castanea dentata*

TABLE V

ANIMAL SPECIES MENTIONED IN TEXT

Mammalia	
Red squirrel	*Tamiasciurus hudsonicus*
Pine squirrel	*T. douglasii*
Red squirrel (Old World)	*Sciurus leucurous*
Eastern gray squirrel	*S. carolinensis*
Western gray squirrel	*S. griseus*
Fox squirrel	*S. niger*
Raccoon	*Procyon lotor*
Fisher	*Martes pennanti*
Marten	*M. americana*
Red fox	*Vulpes fulva*
Common dog	*Canis familiaris*
Domestic cat	*Felis catus*
Anthropoda	
Scabies mite	*Sarcoptes scabiei*
Aves	
Common Crow	*Corvus brachyrhynchas*
Stellars' Jay	*Cyanocitta stelleri*